Research on Ultimate Strength of SWATH under Combined Loads

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ABSTRACT

The research on ultimate strength of SWATH under combined loads is important to ensure its safety. In the present research, nonlinear finite element method is adopted to investigate progressive collapse behaviour of a SWATH model under transverse bending moment, longitudinal torsional moment and combined moments. The interaction of transverse bending moment and longitudinal torsional moment is considered. Ultimate capacity under combined moments with different ratio is researched and discussed. In addition, the influence of loading path on ultimate strength is also analyzed. The interaction between transverse bending moment and longitudinal torsional moment is relatively weak, and so the loading sequence in SWATH.

KEY WORDS: Ultimate strength; SWATH; combined loads; progressive collapse analysis; nonlinear finite element method; interaction action; loading path.

INTRODUCTION

The ultimate strength of ship hull girder represents the survivability of ship structure under extreme seas. It is meaningful to investigate it for improving the safety level as well as rational and reliable ship structural design. For the time being, the assessment method includes one-step method, Smith method, Idealized Structural Unit Method (ISUM), nonlinear finite element method (NFEM) and model test. One-step method is a simple but efficient method to calculate the longitudinal ultimate bending moment. The reduction of bending stiffness after the buckling of deck structure between transverse frames can be considered which lead to the collapse of ship hull girder. One-step method is recommended by Common Structural Rules for Double Hull Oil Tankers (CSR-T) (IACS, 2006). However, it seems not proper to predict the ultimate strength of SWATH because the primary subjected load is transverse bending moment as well as torsion moment. Considering the load shedding after the ultimate strength and the collapse sequence, Smith proposed a progressive collapse analysis method (Smith, 1977). The relationship between vertical bending moment and curvature can be obtained by increasing the curvature of cross section and combining the mechanical properties of each discrete element. It is noted that Smith method is based on the assumption that the cross section remains plane even in post ultimate strength. It has high precision when the ship hull girder is in pure bending. For the situation of combined bending and torsion moments, the precision obtained by Smith method needs further validation. The Idealized Structural Unit Method, refers as ISUM, is a simplified matrix method in which the material nonlinearity and geometric nonlinearity are idealized and included in the element. It is originally proposed by Ueda and Rashed (Ueda, Rashed, 1974). The nonlinear behaviour such as buckling and yielding is idealized introducing lateral shape function. The yielding criterion is also idealized to avoid the integration towards the thickness direction. So, the structural unit with larger size can be regarded as one ISUM element so that the number of degrees of freedom can be reduced significantly as well as computation time. New ISUM elements suiting for complex loading condition are still in developing. The application of ISUM to some special ship shall be comprehensively researched. Model collapse test can reproduce the structural collapse process under specified loading which is the most fundamental and effective way to reveal the physical nature. However, too much money shall be consumed and many influential factors should be taken into account in order to obtain reasonable results.

The material nonlinearity and geometric nonlinearity can be considered in nonlinear finite element method which is the effective numerical analysis method with good adaptability and high accuracy. Such advantages make it more common to be applied to structural collapse analysis, especially for the complex structures under complex loading condition. With the rapid development of nonlinear finite element methods both in theory and computation technologies, many large scale general nonlinear finite element systems, for example ANSYS, ABAQUS, ADINA and MARC, have been widely adopted to analyze ultimate strength of ship structure. For thin-walled structure system such as ship structure, fine mesh size is necessary in order to better simulate the nonlinear behaviour such as buckling/yielding and ensure the accuracy of calculation. As a result, the computation time becomes too long which restricts the wide applications of nonlinear finite element method.

In the present research, progressive collapse analyses of a SWATH under transverse bending, longitudinal torsion and combined bending and torsion are performed using nonlinear finite element software.